

**Redescription of *Proteocephalus sulcatus* (Klaptocz, 1906) (Cestoda: Proteocephalidea), a poorly known parasite of *Clarotes laticeps* (Pisces: Siluriformes) in the Sudan**

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**Redescription of *Proteocephalus sulcatus* (Klaptocz, 1906) (Cestoda: Proteocephalidea), a poorly known parasite of *Clarotes laticeps* (Pisces: Siluriformes) in the Sudan.**- The proteocephalidean cestode *Proteocephalus sulcatus* (Klaptocz, 1906), a poorly known parasite described from widehead catfish *Clarotes laticeps* (Rüppell) and saddled bichir *Polypterus endlicheri* Heckel from the White Nile in the Sudan, Africa, is redescribed on the basis of new material collected in *C. laticeps* caught near the type-locality. New data on the morphology of *P. sulcatus* are provided, based on the first scanning electron microscopical observations and histological sections. The most characteristic features of *P. sulcatus* are: (i) pyriform embryophore; (ii) scolex in form of a four-side truncated cone, with four suckers deeply embedded within lobes with wrinkled posterior margins; (iii) no apical organ; (iv) a low number (1-3) of mature proglottides; (v) a high number (115-171) of testes. *Clarotes laticeps* is considered the only suitable host for *Proteocephalus sulcatus*.

**Keywords:** *Proteocephalus* - Proteocephalidae - cestodes - catfish parasite - *Clarotes laticeps* - Africa - taxonomy.

## INTRODUCTION

Klaptocz (1906) described *Ichthyotaenia sulcata* [(= *Proteocephalus sulcatus* (Klaptocz, 1906) La Rue, 1911)] from several tapeworms found in the intestine of widehead catfish *Clarotes laticeps* (Rüppell, 1829) (Siluriformes: Bagridae) and saddled bichir *Polypterus endlicheri* Heckel, 1847 (Polypteriformes: Polypteridae) from the White Nile in the Sudan. The author provided a morphological description supplemented by 10 not very detailed illustrations (one sketch of the total view of the

tapeworm, three figures of the scolex in dorsoventral view, three figures of the scolex in apical view, one sketch of the oval eggs, one figure of the cirrus-sac and one illustration of the last three proglottids, with details of internal morphology of the two last ones). However, differential diagnosis of *P. sulcatus* from any other species of *Ichthyotaenia* (= *Proteocephalus*) was not included in the original description (Klaptocz, 1906).

Although Khalil (1963) provided some additional data on *P. sulcatus* (see Table 1), the morphology of *P. sulcatus* remains insufficiently known (Freze, 1965) and no data based on histological sections and scanning electron microscopy (SEM) are available. New specimens of *P. sulcatus* found in the intestine of *C. laticeps* from the Sudan made it possible to redescribe the tapeworm and to provide new data on its morphology.

## MATERIALS AND METHODS

Widehead catfish (vernacular name in the Sudan "abu misaika"), *Clarotes laticeps*, were caught by local fishermen in the White Nile at Kostí, about 265 km south of Khartoum, Sudan, on 25-27 March 2006 (other two *C. laticeps* from the fish market in Khartoum examined on 21 March 2006 were free of infection). The fish were examined immediately after their capture, the parasites found were isolated from the host intestine and fixed with hot 4% neutral formaldehyde solution and subsequently

TABLE 1. Comparative measurements (in millimetres unless otherwise stated) of *Proteocephalus sulcatus* from the Sudan.

Host	<i>Polypterus endlicheri</i>	<i>Clarotes niloticus</i>	<i>Clarotes niloticus</i>	<i>Clarotes niloticus</i>
Reference	Klaptocz (1906)	(1906)	Khalil (1963)	Present study
Total length	48-68	60	65-95	36-57
Maximum width	-	-	1.2-1.8	1.48
Scolex				
length	-	-	1.2-1.3	0.66-1.07
width	0.75-1.72	0.67-1.28	1.4-2.0	0.80-1.26
Diameter of suckers	0.25	-	-	0.28-0.45
Mature proglottids				
length	2	1.54	1.6-2.3	0.47-1.31
width	1.5	1.9	1.0-1.9	0.92-1.41
Number of testes	about 200		117-130	115-171
Cirrus-sac (in $\mu\text{m}$ )				
length	-	-	290-310	190-300
width	-	-	160-180	120-150
Uterine diverticula	-	-	11-13	15-22
Eggs (in $\mu\text{m}$ )				
length	29	-	-	26-28
width	16	-	-	16-18

stored in 70% ethanol. The specimens were then stained with Mayer's hydrochloric carmine solution, dehydrated in an ethanol series, cleared with eugenol (clove oil) and mounted in Canada balsam.

Pieces of strobila were embedded in paraffin wax, sectioned at 12-15  $\mu\text{m}$  (cross sections of the strobila and longitudinal and sagittal sections of two scoleces), stained with Weigert's haematoxylin and counterstained with 1% eosin B (Scholz & Hanzelová, 1998; de Chambrier, 2001). Eggs were studied in distilled water. Three specimens (scolex with the anterior part of the strobila) were used for SEM observations using the procedure outlined by de Chambrier *et al.* (2008).

All measurements are given in micrometres unless otherwise indicated. Abbreviations used in descriptions are as follows:  $\bar{x}$  = mean,  $n$  = number of measurements, OV = ratio of ovary width versus proglottis width (in %), PP = position of genital pore (cirrus pore) in % of proglottis length, PC = ratio of cirrus-sac length versus proglottis width (in %). MHNG INVE = Natural History Museum, Invertebrate Collection, Geneva, Switzerland; IPCAS = Institute of Parasitology, České Budějovice, Czech Republic.

***Proteocephalus sulcatus* (Klaptocz, 1906) La Rue, 1911**

Figs 1-21

Syn.: *Ichthyotaenia sulcata* Klaptocz, 1906

**Redescription:** Proteocephalidea, Proteocephalidae. Testes, ovary, vitelline follicles, uterus with uterine stem and diverticula medullary. Strobila with slightly craspedote proglottides (Fig. 7), 36-57 mm long and up to 1.48 mm wide (Table 1).

Proliferative zone about 700-1100 long and 360-775 wide. Strobila consisting of 94-120 proglottides: 43-70 immature (up to appearance of spermatozoa in vas deferens), only 1-3 mature (up to appearance of eggs in uterus), 24-36 pregravid (up to appearance of hooks in oncospheres) and 26-38 gravid.

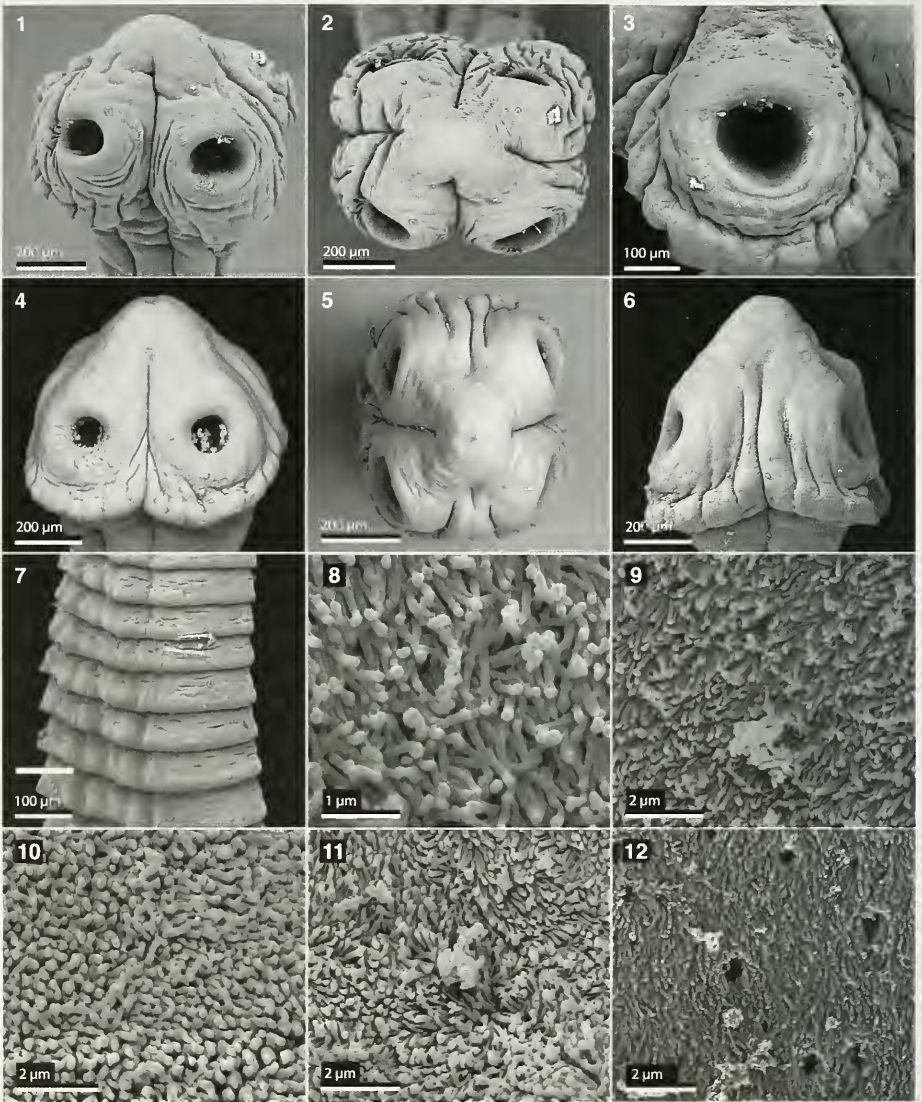
Scolex unarmed, wider than neck, about 810-1260 in diameter, and about 665-1070 long. Scolex a four-sided truncated cone. Suckers uniloculate, 280-450 in diameter, paired on opposite sides of cone, separated by deep incisions; two sides without sucker also divided by deep incisions. Distinct apron of tissue posterior to suckers, longitudinally wrinkled (Figs 1-6). Apical organ absent (Figs 13-15).

Scolex, proliferative zone and anterior proglottides covered uniformly with relatively short and wide filiform microtriches, only slightly differing from each other in their shape, length and density (Figs 8-12), except for those of proliferation zone, which are notably smaller.

Longitudinal internal musculature well developed, anastomosing, forming wide band of dense muscle bundles; muscle bundles becoming slightly wider near lateral margins, at level of lateral vitelline follicles (Figs 19, 20). Numerous dorsoventral muscle fibres present. Subtegumental muscles well developed.

Ventral osmoregulatory canals wide, thin-walled, without anastomoses, overlapping lateralmost testes. Dorsal osmoregulatory canal thick-walled, overlapping dorsally vitelline follicles (Figs 16, 20).

Testes medullary, spherical to oval, 55-120 in diameter, numbering 115-171 ( $n = 9$ ,  $\bar{x} = 143$ ; about 200, according to Klaptocz, 1906), in two or three incomplete layers, forming two fields confluent anteriorly, with more testes laterally (Figs 16, 19).



FIGS 1-12

*Proteocephalus sulcatus* (Klaptocz, 1906) from *Clarotes laticeps*, Kostí, Sudan (MHNG INVE 54146: 1, 2, 12; MHNG INVE 54141: 3-5; MHNG INVE 54140: 6-11). Scanning electron micrographs. (1) Scolex, dorsoventral view. (2) Scolex, apical view. (3) Scolex, detail of a sucker, showing the plicated tissue posterior to sucker. (4) Scolex, dorsoventral view. (5) Scolex, apical view. (6) Scolex, lateral view. (7) First immature, markedly craspedote proglottides. (8) Filiform microtriches on apex of scolex. (9) Filiform microtriches on anterior external margin of suckers. (10) Filiform microtriches on internal surface of suckers. (11) Filiform microtriches between suckers. (12) Filiform microtriches on external surface of proliferation zone (neck). Scale bars: 1, 2, 4-6 = 200  $\mu$ m; 3, 7 = 100  $\mu$ m; 8 = 1  $\mu$ m; 9-12 = 2  $\mu$ m.

External vas deferens strongly coiled, reaching midline of proglottis, never crossing it aporally. Internal vas deferens thin-walled, very short; ejaculatory duct thick-walled, long, forming several loops; cirrus long, may occupy complete length of cirrus-sac. Cirrus-sac elongate, thick-walled, 190-300 ( $x = 242 \pm 22$ ;  $n = 42$ ;  $CV = 9\%$ ), 120-150 wide (L/W ratio = 1.65-2.15,  $x = 1.85$ ). PC = 16-23% ( $x = 20 \pm 1.5\%$ ;  $n = 42$ ;  $CV = 8\%$ ). Genital pore irregularly alternating, pre-equatorial, situated at 27-46% ( $x = 36 \pm 4\%$ ;  $n = 42$ ;  $CV = 11.4\%$ ) of proglottis length. Genital atrium present (Figs 16, 17).

Ovary bilobed, medullary, with numerous lobules extending ventrally (Figs 16, 20). OV = 64-71% ( $x = 68 \pm 2\%$ ;  $n = 42$ ;  $CV = 3\%$ ). Mehlis' glands about 100-180 in diameter, representing 8-17% of proglottis width. Vagina thick-walled, always posterior to cirrus-sac ( $n = 150$ ), with higher concentration of chromophilic cells in its distal (terminal) part, with terminal ring-like vaginal sphincter, difficult to observe in mature proglottides. Vitelline follicles in two longitudinal bands on both sides of proglottis, occupying almost its total length; bands interrupted at level of terminal genitalia on ventral side, with few follicles on dorsal side (Figs 16-18).

Uterus medullary, with development of type 1 according to de Chambrier *et al.* (2004), defined as follows: In immature proglottides, uterine stem present as longitudinal concentration of chromophilic cells along median line. Lumen of uterus appears in last premature proglottides, gradually extending to form tubular structure. Eggs appear simultaneously with formation of lateral, thick-walled diverticula lined with chromophilic cells. In gravid proglottides, lateral diverticula remain thick-walled, 15-22 in number on each side, occupy up to 77% of proglottis width (Fig. 18).

Eggs with hyaline, ring-like outer envelope, about 35-42 in diameter; thick, pyriform embryophore 26-28 long by 16-18 wide, consisting of two layers; outer layer thicker than nuclei-containing envelope; oncospheres spherical to oval, 9-10 by 12-13 in diameter, with six embryonic hooks 5-6 long (Fig. 21).

#### TAXONOMIC SUMMARY

*Type-host*: not designated (see Discussion).

*Type-locality*: White Nile, between Khartoum and Fachoda (Kodok).

*Definitive hosts*: widehead catfish *Clarotes laticeps* (Rüppell) and saddled bichir *Polypterus endlicheri* Heckel.

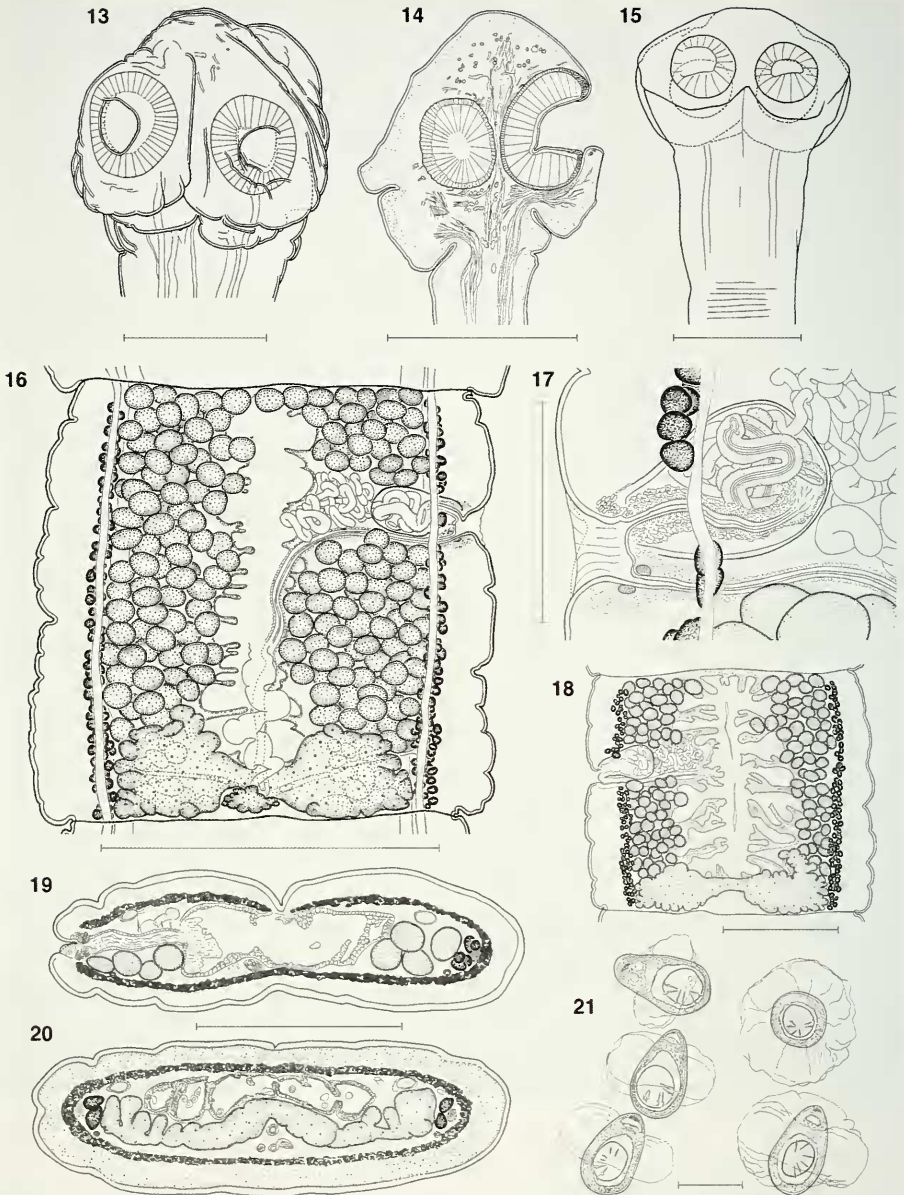
*Material studied*: 35 specimens collected by A. de C. & T. S. in 8 *C. laticeps* from the White Nile at Kostí, Sudan (MHNG INVE 54139, 54140, 54141, 54145, 54146, 54147; IPCAS C-470/1). Five specimens from *C. laticeps* from the Sudan (Khartoum) collected by L. F. Khalil in 1959 (MHNG INVE 34798).

*Site of infection*: intestine.

*Prevalence*: 73% (infected 8 of 11 fish examined).

*Intensity of infection*: 1-10 tapeworms (mean 4.4).

*Distribution*: White Nile in the Sudan. Reports of *P. sulcatus* from *Chrysichthys* sp. from Belgian Congo (now Democratic Republic of the Congo – de Beauchamp, 1914; Mahon, 1954) represent in fact *Proteocephalus beauchampi* Fuhrmann & Baer, 1925 (Fuhrmann & Baer, 1925; Khalil, 1971).



FIGS 13-21

*Proteocephalus sulcatus* (Klaptocz, 1906) from *Clarotes laticeps*, Kostí, Sudan (MHNG INVE 54145: 13; MHNG INVE 54147: 14; MHNG INVE 34798: 15; IPCAS C 470/1: 16, 17; MHNG INVE 54139: 18; MHNG INVE 54140: 19-21). (13, 15) Scolex, dorsoventral view. (14) Scolex, sagittal section. (16) First pregravid proglottis, dorsal view. (17) Terminal genitalia, dorsal view. (18) Gravid proglottis, dorsal view. (19, 20) Cross sections. (21) Eggs (egg on the right of the upper line figured from *en face* view). Scale bars: 13-15, 18-20 = 500  $\mu\text{m}$ ; 16 = 1000  $\mu\text{m}$ ; 17 = 250  $\mu\text{m}$ ; 21 = 20  $\mu\text{m}$ .

## DISCUSSION

The present study, which included for the first time SEM observations and histological sections, confirmed the validity of *Proteocephalus sulcatus*. The species possesses several characteristics missing or rare in other proteocephalideans, including those parasitic in African freshwater fish (Beauchamp, 1914; Fuhrmann & Baer, 1925; Khalil, 1960, 1963; Lynsdale, 1960; Freze, 1965; Jones, 1980; de Chambrier *et al.*, 2008). The most typical characters of *P. sulcatus* are: (i) pyriform embryophore of the eggs; (ii) scolex a four-sided truncated cone, with deep incisions between suckers and posterior longitudinal wrinkles; and without apical organ; (iii) only 1-3 mature proglottides present; (iv) a fairly high number of testes (115-171), arranged in 2-3 incomplete layers.

De Beauchamp (1914) reported *P. sulcatus* from *Chrysichthys* sp. from Kilewa Bay of Lake Tanganyika, Belgian Congo (currently Democratic Republic of the Congo), but a new species, *Proteocephalus beauchampi*, was proposed to accommodate this tapeworms (Fuhrmann & Baer, 1925). Mahon (1954) also reported *P. sulcatus* from *Chrysichthys* sp. from Congo, but it is possible that she probably found *P. beauchampi* as well, because *P. sulcatus* has not been found in congeneric fish hosts (*Chrysichthys* sp.) from the White Nile, examined by the present authors in 2006 (unpublished data). Khalil (1963) provided a brief description of the morphology of several specimens of *P. sulcatus* he found in *Clarotes laticeps* from Khartoum area in the Sudan (Table 1) and illustrated rather schematically an allegedly mature proglottis (possibly pregravid or gravid one – see fig. 1 in Khalil, 1963). The present study confirmed most of Khalil's (1963) measurements (see Table 1), except for the number of uterine diverticula, which is in fact much higher than reported by Khalil (1963) (15-22 vs 11-13 on each side).

Besides *P. sulcatus*, only two proteocephalidean cestodes possess pyriform embryophores similar to those of *P. sulcatus*, namely *Proteocephalus beauchampi* Fuhrmann & Baer, 1925 from *Chrysichthys* catfishes in Africa and *Amphoteromorphus piriformis* Carfora, de Chambrier & Vaucher, 2003, a parasite of pimelodid catfish *Brachyplatystoma flavicans* (Lichtenstein) in the Neotropical Region (de Beauchamp, 1914 – as *P. sulcatus*; Freze, 1965; Carfora *et al.*, 2003). Morphology of the eggs has been proved suitable for species differentiation in some proteocephalidean tapeworms (Scholz, 1999; Gil de Pertierra & de Chambrier, 2000; Carfora *et al.*, 2003) and we strongly recommend that morphological descriptions contain detailed data on egg morphology.

*Proteocephalus beauchampi*, a parasite of bagrid catfish of the genus *Chrysichthys* in Africa, resembles *P. sulcatus* in possessing a somewhat similar scolex without an apical organ, but it differs in the absence of posterior longitudinal wrinkles (Fuhrmann & Baer, 1925). De Beauchamp (1914) observed in his material of *P. beauchampi* (designated as *P. sulcatus*) also pyriform embryophores of similar shape and size (25 by 18  $\mu\text{m}$ ). However, the two taxa differ from one another in strobilar morphology, especially position of the vagina [always posterior in *P. sulcatus* and anterior (44%) and posterior (56%) in Khalil's material of *P. beauchampi*] and the number of testes (57 figured according to fig. 1 of de Beauchamp, 1914). We were not able to locate the type material of both species. Previous records of *P. sulcatus* from

other catfish, such as *Chrysichthys brachynema* and *Chrysichthys* sp. (Prudhoe, 1951; Mahon, 1954; Khalil & Polling, 1997), are so considered to belong to *P. beauchampi*.

SEM observation of the surface of the scolex, neck and anterior part of the strobila of *P. sulcatus* has shown the presence of relatively short and wide filiform microtriches, with only slight differences in their shape, size and density between individual body regions. Only the anterior part of the strobila shows somewhat smaller filiform microtriches, but of the same shape. This uniformity in the shape of microtriches differs from that found mainly in Neotropical members of the Proteocephalidea studied using SEM, such as species of the genera *Nomimoscolex* Woodland, 1934 and *Monticellia* La Rue, 1911 (de Chambrier & Vaucher, 1999; Rego *et al.*, 1999; Gil de Perterra, 2002, 2004, 2005; de Chambrier *et al.*, 2005, 2006).

*Proteocephalus sulcatus* was described on the basis of tapeworms from two unrelated fish hosts, a catfish and a bichir, because Klaptocz (1906) considered slight differences between them, especially in the shape of the scolex, to be accounted for by intraspecific variability. The type-host was not designated, although Khalil (1963 – p. 309) considered saddled bichir *Polypterus endlicheri* to be the type-host because it was listed first in the text of Klaptocz' (1906) original description. However, the following data indicate that widehead catfish *Clarotes laticeps* should be considered the actual type-host of *P. sulcatus*: (i) the original description was mainly based on larger tapeworms from widehead catfish *Clarotes niloticus* (see Klaptocz, 1906 – p. 123); (ii) saddled bichir harboured less and smaller tapeworms (Klaptocz, 1906 – p. 123); (iii) Khalil (1963) did not find any *P. sulcatus* tapeworms in 322 *P. endlicheri*, *P. bichir* Lacépède and *P. senegalus* Cuvier from the White Nile in the Sudan (see also Jones, 1980); (iv) the present authors also did not find *P. sulcatus* in eight specimens of *Polypterus*, mainly *P. senegalus*. On the other hand, eight out of nine widehead catfish *Clarotes laticeps* examined in Kosti were infected.

On the basis of the above-listed facts, *Clarotes laticeps* is considered to be the type- and most probably the only actual definitive host of *P. sulcatus*. Klaptocz' (1906) finding of *P. sulcatus* in saddled bichir may have represented an accidental infection via predation of widehead catfish and the bichir served as a postcyclic host (see Odening, 1976 for terminology of host categories). This latter assumption is supported by the fact that saddled bichir is essentially piscivorous and that the infected *P. endlicheri* specimen was extremely large (total length 622 mm according to Klaptocz, 1906, thus reaching to the maximum standard length reported for the species, which is 630 mm – Froese & Pauly, 2007).

Klaptocz (1906) described another species of *Proteocephalus*, *P. pentastoma* (syn. *Ichthyotaenia pentastoma* Klaptocz, 1906), from Nile bichir, *Polypterus bichir* Lacépède, 1803, from the White Nile in the Sudan. This cestode is a specific and relatively common parasite of bichirs in the Sudan (Jones, 1980), but it is markedly different from *P. sulcatus*, especially in possessing a muscular apical sucker and vitelline follicles arranged in a transverse band posterior to the ovary with anterior longitudinal arms along the lateral margins of proglottides (Jones, 1980).

*Proteocephalus sulcatus*, which is considered here to be a specific parasite of *Clarotes niloticus*, has hitherto been found only in the Nile River in the Sudan. However, it probably also occurs in the Nile River basin in other countries of north-eastern Africa.



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